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BXO EFFICIENCY OF THREE DATA-GATHERING METHODS FOR STUDY OF LOG-MAKING ACTIVITIES

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ABSTRACT

Three data-gathering methods — continuous reading, work sampling, and time-lapse photography — were used for accumulating log-making information. Using the estimates from the continuous reading method as the standard, work sampling offered economy at no sacrifice in accuracy for giving an unbiased breakdown of daily work time into felling, limbing and bucking, extra buck cuts, and travel plus unproductive time. When travel and unproductive time were considered separate elements, continuous reading provided the only unbiased estimates.

The objective of this study was to evaluate the efficiency of two data-gathering methods — work sampling and time-lapse photography — for studying the daily activities of sawyers. A third method — continuous reading — was used to obtain data to use in evaluating the aforementioned methods because continuous reading is assumed to reveal dependable values even though it might not be the most economical method.

The work sampling method used involved random observations. Another type of work sampling, in which observations are made on a systematically distributed basis, was considered. However, we rejected it because of the danger of reaching false conclusions if the sawyer's activities shifted into phase with the predetermined intervals. Furthermore, it was rejected because the predetermined sample interval would have had to be sufficiently small to provide at least one observation from each of the four activities studied: (1) felling; (2) limbing and bucking; (3) travel from tree to tree; and (4) extra bucking cuts because of defects.

Continuous filming, which is another type of photographic method, was rejected because of the high cost involved. All of the methods considered are probably among the methods most widely used in logging studies; however,

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we recognize other sampling methods are available, such as those described by Ferber[2] and Madow.[3]

We were particularly interested in testing the time-lapse photography method because it has won widespread use in production-line industries and offers the following advantages: (1) it provides permanent proportional-time records for observing methods, work patterns, safety practices, and worker distributions when the activities can be delineated; (2) it requires less training of those charged with gathering the data; and (3) it is not as tedious.

STUDY METHODS

The data were gathered at two logging locations on the Gallatin National Forest in Montana — Wild Horse Creek and East Fork Hyalite Creek. Our crews took data for three complete workdays at the Wild Horse Creek site and then gathered data on the fourth day on the East Fork Hyalite Creek site.

We assigned two men to taking continuous readings and one man each to the work sampling and time-lapse photography. The continuous reading method required two observers because one observer could not work the stopwatches, record the times, and dodge snags and falling trees all at the same time.

Continuous Reading

All activities of the sawyer were accounted for in minutes and fractions of minutes. Immediately after a sawyer stopped one activity and began another, the elapsed time of the first activity was recorded. They proceeded as follows: Observer 1 started time on watch 1; at the instant sawyer activity changed, he simultaneously stopped watch 1 and started watch 2. Stopwatch 1 was read, reset to zero, and the time called to observer 2. Observer 2 noted the activity in progress for that time and recorded the time under the proper activity.

Observer 1 was told that if he ever punched both watches before a true change in activities became obvious, he was to note immediately the time on the stopped watch, reset it to zero, and when certain of an activity change, punch both watches, thus stopping one and starting the other, as explained above. The correct activity time in this case would be the noted time plus the time on the watch just stopped. Fortunately, this type of error did not turn up. At the end of the day, the total time for each activity was adjusted to a percent of total daily time. For instance, on the first day operations were studied, the total time spent felling amounted to 55.18 minutes, while the total time on the job less lunch breaks was 427 minutes; hence, the percent of time spent felling was 12.92 (see table 1).

Work Sampling[4]

By studying figure 1, it is easy to obtain a clear idea of how our observer recorded his observations. The two digits following each minute represent seconds. These were changed for each of the 4 days on which we gathered data. The changes were selected at random, based upon a random timetable published by Lambrou.[5]

The observer determined a sawyer's activity at precisely the indicated number of seconds past a minute, and recorded the proper activity code letter next to that minute. For example, on the first study day at 15 seconds past 0923, the observer spotted the sawyer in the act of felling. (After recording the letter "F," the observer saw that he had to be alert for the next observation at 55 seconds past 0924.)

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[2] *Ferber, Robert. Market research. 542 pp., illus. New York: McGraw-Hill Book Co., Inc. 1949.*

[3] *Madow, L. H. Systematic sampling and its relation to other sample designs. J. Amer. Statist. Assoc. 41(234): 204-217. 1946.*

[4] *For more information on this method, see Barnes, Ralph M. Work sampling. 2d Ed., 283 pp. New York: John Wiley & Sons. 1957.*

[5] *Lambrou, F. H. Guide to work sampling, part IV. 106 pp., illus. New York: John F. Rider Publ., Inc. 1962.*

Observations were taken at some point within each minute except during lunch breaks. Notice on figure 1 that recording began at 0921 and stopped at 1118, when the sawyer ate a sandwich. He resumed work at 1132, not stopping again until 1358 for more of his lunch. His next work span was from 1414 to 1513, and his final one from 1528 until he chose to quit at 1713. This gave a total number of 427 code letters for the first day.

Each group of code letters was totaled at the end of the day and the activity corresponding to the code letters was adjusted to a percent of the total daily code letters.

Time-Lapse Photography

Our observer used a camera that could be operated at lapses between frame exposures ranging from 1 to 120 seconds. We chose the 10-second interval because it permitted us to collect a maximum of observations on each roll of film for the longest workday expected.

When the continuous reading and work sampling began, the observer switched on a battery-powered exposure device that automatically snapped a picture every 10 seconds. During the rest of the day, he merely repositioned the camera and adjusted its lens settings.

After the film was developed, activities shown on the frames were counted for each category of activity. For instance, 342 frames were counted for felling out of a total of 2,562 frames for the first study day.

RESULTS AND DISCUSSION

Confidence limits were established at the 5-percent level for the estimates derived from the work sampling and time-lapse photography methods. These confidence limits are shown in table 1 and were computed as follows:

$$p-1.96\phi \leq P \leq p+1.96\phi,$$

where

$\phi = \sqrt{\frac{p(1-p)}{N}}$, the standard error for the sample estimate of proportions

p = ratio of the number of observations for each activity to the total daily observations for all activities, or proportion of workday by activity

P = ratio of continuous reading times to total daily times

N = total number of daily observations.

When the estimate of the mean for continuous reading didn't fall within the corresponding confidence limits, the corresponding sample mean derived from either the work sample or time-lapse photography methods was considered to contain bias. The estimates of the means derived from the continuous reading method were considered, of course, to be without bias for all activities. The percentage of the workdays on which apparent bias was absent is shown in the following tabulation:

Activity	*Work sampling*	*Time-lapse photography*
Felling	100	50
Limbing and bucking	100	0
Travel, tree to tree	0	25
Extra buck cuts	100	0
Unproductive	0	0

The presence of apparent bias for any of the 4 observation days suggests that the estimating method contains objectionable inaccuracies.

CONCLUSIONS

The time-lapse photography method proved to be unacceptable because it was difficult to delineate the activities in the pictures. Undergrowth and slash obscured over 55 percent of the observations. The observers were forced to keep continually on the move, either to stay in the range of the sawyer's activities or to retreat from falling trees and snags. Such movements in and out of shadows forced frequent adjustments to be made in lens settings, and these adjustments were often forgotten. Thus, we were able to make only "best estimates" about a sawyer's activities in over half of the pictures taken.

The work sampling method proved unreliable for recording travel from tree to tree, which in turn affected recording of unproductive times. At a glance, an observer knew whether the activity performed was felling, limbing and bucking, or extra bucking because of defect. However, he could not always be certain whether a walking sawyer was productive or unproductive, because any instantaneous observation of a walking sawyer introduced one of three possibilities: (1) he is returning to a tree butt to begin bucking; (2) he is walking to his fuel cans or a resting place; or (3) he is walking to the next tree to fell it. To fulfill the requirement of recording instantaneous random observations, it was impossible for the observer to delay long enough to be certain of a sawyer's activity without introducing excessive bias.

Therefore, the work sampling method offers economy at no sacrifice in accuracy for estimating the breakdown of daily work time into felling, limbing and bucking, extra buck cuts, and travel plus unproductive activities. But where travel and unproductive times must be separated, continuous reading provides the only unbiased measurements.

In retrospect, we feel that the systematic predetermined interval type of work sampling would have provided accurate estimates and recommend consideration of its use in similar studies.

Figure 1. — Sample of daily observation sheet. On an actual sheet, 1-minute intervals are listed for 11 hours. This sample was shortened for reproduction purposes; three dots (. . .) indicate intervening time.

STUDY:	SAWYER:
AREA:	DATE:

0700-00-	0923-15-F	1120-05-	1355-35-L	1414-00-F	1515-50-	1711-05-L
0701-40-	0924-55-L	1121-20-	1356-10-L	1415-50-U	. . .	1712-35-U
0702-15-	0925-50-L	. . .	1357-50-U	1416-10-L	1526-05-	1713-15-
0703-00-	0926-50-U	1130-10-	1358-15-	1417-30-L	1527-05-	1714-20-
0704-25-	. . .	1131-35-	1359-05-	. . .	1528-55-B	. . .
. . .	1115-25-T	1132-25-T	1400-30-	1510-00-L	1529-35-L	1800-00-
0919-05-	1116-40-U	1133-25-L	1401-25-	1511-55-U	1530-20-L	
0920-30-	1117-10-F	1134-40-B	. . .	1512-15-F	. . .	
0921-45-F	1118-30-	1135-20-L	1412-20-	1513-30-	1709-05-T	
0922-00-F	1119-15-	. . .	1413-55-	1514-35-	1710-50-F	

-ACTIVITY CODING-

F - Felling
L - Limbing and Bucking
T - Travel from Tree to Tree
B - Extra Buck Cuts because of Defect
U - Unproductive Time

Table 1. — Confidence limits for estimates of time devoted to log-making activities using work sampling and time-lapse photography methods of data gathering[1]

(In percent of daily work time)

Study day	Activity	Continuous reading[2]	Work Sampling			Time-lapse photography		
		Mean estimate	Mean estimate	Lower limit	Upper limit	Mean estimate	Lower limit	Upper limit
1	Felling	12.92	13.81	10.54	17.08	13.34	12.02	14.66
	Limbing and bucking	37.38	36.07	31.51	40.62	45.67	43.74	47.60
	Travel, tree to tree	6.44	14.99	11.60	18.38	7.96	6.91	9.01
	Extra buck cuts	1.29	1.87	0.58	3.15	0.71	0.38	1.03
	Unproductive	41.97	33.26	28.79	37.73	32.32	30.51	34.13
		100.00	100.00			100.00		
2	Felling	17.51	18.85	15.17	22.53	11.03	9.83	12.23
	Limbing and bucking	42.21	40.46	35.85	45.07	28.74	27.00	30.48
	Travel, tree to tree	5.21	12.18	9.11	15.25	11.03	9.83	12.23
	Extra buck cuts	0.51	0.69	—0.09	1.47	1.15	0.74	1.56
	Unproductive	34.56	27.82	23.61	32.03	48.05	46.13	49.97
		100.00	100.00			100.00		
3	Felling	12.53	13.54	10.21	16.87	13.79	12.42	15.16
	Limbing and bucking	31.92	30.79	26.30	35.28	35.96	34.05	37.86
	Travel, tree to tree	3.90	9.11	6.31	11.91	4.43	3.61	5.25
	Extra buck cuts	1.14	1.73	0.46	3.00	0.49	0.21	0.77
	Unproductive	50.51	44.83	39.99	49.67	45.33	43.35	47.31
		100.00	100.00			100.00		
4	Felling	9.62	10.25	7.41	13.09	11.16	9.96	12.36
	Limbing and bucking	28.97	27.79	23.60	31.98	34.85	33.03	36.67
	Travel, tree to tree	3.12	7.29	4.86	9.72	8.65	7.58	9.72
	Extra buck cuts	3.02	4.32	2.42	6.22	6.84	5.88	7.80
	Unproductive	55.27	50.35	45.67	55.03	38.50	36.64	40.36
		100.00	100.00			100.00		

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[1] *Confidence limits were determined using the mathematical expression shown under "Results and Discussion" and can be expected to be correct 95 percent of the time.*

[2] *As explained in the text, the estimated means derived using the continuous reading method were used as a standard for judging the accuracy of estimated means derived using the other two methods.*